RUTH SOFAIR KETLER

Decookbook It!

By Thomas W. Shiland

Encourage inquiry by modifying traditional elementary chemistry laboratory activities.

TEACHERS CAN MODIFY many traditional elementary chemistry experiments to move students toward the *National Science Education Standards*. According to the *Standards*, elementary students should have certain abilities necessary for scientific inquiry, including being able to ask questions that can be answered by an experiment and to plan and conduct simple investigations to answer these questions in the manner of a "fair test," where only one variable at a time is changed (National Research Council, 1996, p. 122).

Some transitional activities are needed to bridge the gap between traditional "cookbook" activities and the type of inquiry envisioned by the *Standards*. Many students have enjoyed a number of cookbook activities—how can these activities be modified to move toward inquiry?

To help students become more familiar with inquiry, I have modified three familiar activities: paper chromatography, play dough, and the "Cat's Meow."

These transitional activities were used with three classes of fourth- and fifth-grade students during five mornings of an optional Saturday morning program. These students had been identified as being academically talented; however, **all** students would enjoy and learn as they participate in these three activities.

In this program, students expected to do interesting "hands-on" activities, but first we needed some ground rules. The program began with a discussion of safety and the habits of good scientists. Safety concerns were addressed by asking the students for rules to keep everyone safe during experiments. Students quickly volunteered that following directions and not tasting chemicals were important rules. I added that students should tell the teacher if they are hurt, and to be watchful of their neighbor, since we would be working in groups. I also added that certain activities may require eye protection, and I passed out goggles for students to use when needed.

In the same manner, I asked for the habits of good scientists. Students volunteered that good scientists ask questions and make careful observations. I added that working well in a group and trying to relate the experiment to something we already know were also important. The students wrote these habits and the safety requirements in the front of a small, inexpensive "lab notebook" they had been given.

Paper Chromatography

I introduced the students to experimental design with a paper chromatography experiment. To begin, I told the students the etymology of the word *chromatography*, "chroma" coming from the Greek word meaning color and "graphy" coming from the Greek word meaning writing.

The materials needed for each group of four are

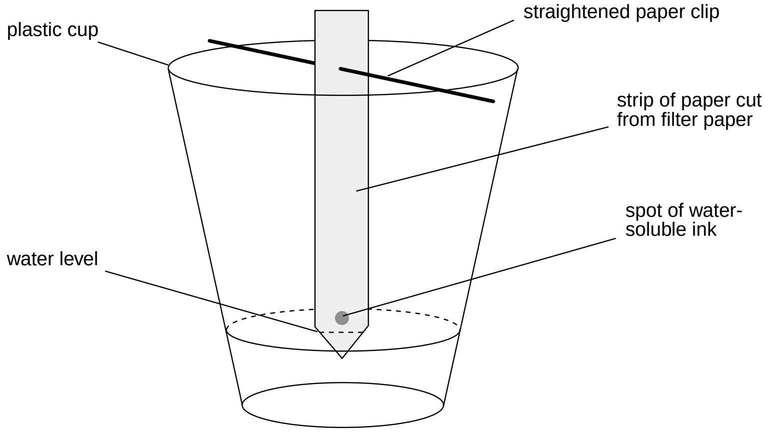
- a water-soluble, black pen,
- a container of water,
- four large paper clips,
- four clear plastic cups,
- four pairs of scissors,
- four small metric rulers,
- four pieces of filter paper,
- different-colored water-soluble pens (six different colors for the class),
- water at different temperatures,
- different types of paper,
- different types of liquids, e.g., rubbing alcohol (optional),
- and safety goggles, if liquids other than water are used.

Each student was instructed to cut out a strip of filter paper that was 12 cm long and 2 cm wide with a V-shape at one end. A diagram of this was put on the board for them to follow. The exact dimensions are not critical, but it gives them practice making measurements, which is part of the *Standards* expectations for this age group.

Using the water-soluble pen, students placed a dot of ink on the strip of filter paper at the top of the point (see Figure 1, next page). Students then put a straightened paper clip through the opposite end of the strip and placed the paper clip across the top of the cup. The pointed end of the strip was placed in the water with the dot just above the water.

While students waited for the ink pigments to separate, I introduced the topic of operational questions, which are questions that can be answered by experiment. To begin an understanding of operational questions, I asked students to list the things they could change (variables) in their experiment. Students gave responses that included the type of ink, water temperature, type of liquid, type of paper, size of dots, and number of dots.

Figure 1. Paper Chromatography.



> ***Students were creative with their experiment designs. Some students asked, "What is the effect of making a heavier dot of ink on the paper?" and "What is the effect of making multiple dots?"***

Having the students focus on what they can change is a way to get them thinking about the properties of the materials involved, which is a *Standards* goal for this age group. (For example, the paper used could be a paper towel, typing paper, newspaper, or cardboard. These materials have different properties that might affect the result.)

After about 10 minutes, the ink separated into different colors. The students were surprised that a black ink could produce different colors. I asked the students to make some observations and then refine their observations in writing.

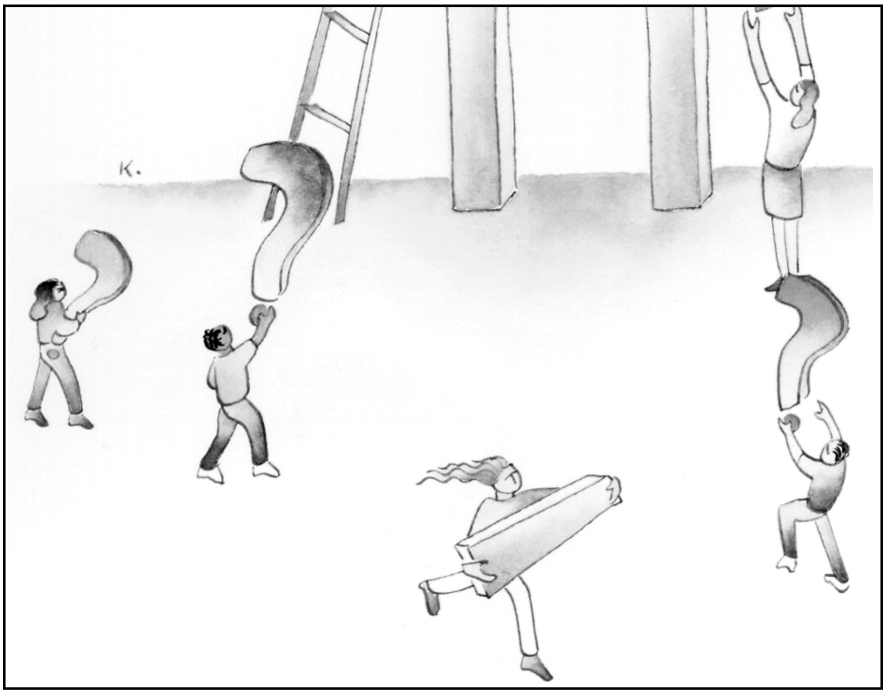
To help the students, I asked questions such as "Which colors traveled the farthest?" I also asked the students if the order of the colors was always the same (it was). Some students had placed their dot so that it was in the water, instead of just above it. This did not produce a nice separation of colors. I pointed out that the black ink was an example of a "mixture," a type of material that could be separated into parts.

I then asked students to write an operational question for each of the following categories: substitution, increasing/decreasing, or elimination (Allison and Shrigley, 1986). "Substitution" means to ask what would happen if something could be substituted for a variable. "Increasing/decreasing" means to ask a question concerning something that can be increased or decreased. "Elimination" means to ask what would happen if a variable was eliminated. The students were then asked to pick the question they liked best and identify all the variables that must be held constant.

The student-designed experiments were then carried out. Students were creative in their designs. For increasing/decreasing, some students asked, "What is the effect of making a heavier dot of ink on the paper?" and "What is the effect of making multiple dots?" Substitution questions included, "What is the effect of substituting a different paper for the filter paper?" and "What is the effect of substituting hot water for room temperature water or using a different liquid?"

It would be appropriate for students to use goggles. Teachers must review each question before the experiment is carried out to take **all** appropriate safety measures.

Eliminating variables was not a popular experiment, probably because the students expected nothing would happen.



Tips for Modifying Activities to Introduce Experimental Design

- Choose activities that are easily and cheaply modified. (For example, varying the type of cereal in investigating iron content can be expensive!)
- Anticipate variables ahead of time (e.g., needing hot water or ice water).
- Have students write out their plan as a condition to begin any experiment. Students are anxious to "do something" without the benefit of a written plan. At a minimum, their plan should include the question they are going to investigate, the variables they are going to hold constant, and what they will use to compare the results.
- Medicine cups (30 mL, graduated in a number of units) make excellent containers for an increase/decrease variable. I obtain these inexpensive cups from a medical supply store.
- Experimental design need not be the only type of laboratory experience the student has. As previously mentioned, it may too expensive to buy all the cereals necessary to have the students investigate a substitution question concerning iron in cereals, but it still may be worthwhile to see that some cereals have iron in them.
- Choose activities that are safe to vary and intrinsically interesting. Some activities may actually be too interesting—students lost interest in trying to make the *best* soap bubble mix because any type of mix created bubbles to blow out the windows!
- Experiments that do not work are a part of science and recording observations for them is as important as when they do work. My class is still searching for the right mix to make "moo glue," a glue from milk.

After the experiments were complete, students compared their new results with the original results. Students discovered that paper substitutions that were not absorbent, like cardboard, did not separate the ink well. Heavier dots and changing the width or the length of the paper did not affect the results dramatically. Certain types of water-soluble pens (red pens) did not separate into different colors.

An Optimal Play Dough

A second activity related to experimental design was to design an optimal mix of ingredients for "play dough." As in the first activity, key ideas in the *Standards* are being addressed. The students are asking questions that can be answered experimentally, planning investigations, and becoming familiar with the idea of a "fair test." They are making observations about the properties of materials; some of these properties require equipment to measure. This may be used to introduce the properties of solids and liquids.

For this activity, students in groups of four used

- a labeled coffee can of flour,
- a labeled coffee can of salt,
- a large container of water,
- four aluminum pie plates,
- two measuring cups,
- and vegetable oil (for possible modifications).

The recipe I provided used a two-to-one ratio of flour to salt, but the corresponding water amount was left out. I gave students a simple blank chart and asked them to fill in columns for the variables (flour, salt, and water) and the results.

In the Cat's Meow, students become familiar with posing questions that can be answered experimentally.

Before students began, I instructed each student in a group to try a different amount of water. Each group reported its results on a chart on the blackboard for the class. Once again, students learned about the idea of a "fair test," holding all variables except one constant and making observations on the results of changing one variable, the water.

Students used the measuring cups to determine quantities of flour, salt, and water. They were also allowed to experiment with adding a small amount of vegetable oil, which most felt improved the mix. Students were then allowed to make up a larger batch of the "best mix," as determined by the class, to take home.

Cat's Meow

A third activity that proved successful in teaching experimental design was a modification of the "Cat's Meow." In this activity, students are becoming familiar with posing questions that can be answered experimentally, designing and conducting investigations, and communicating results.

For this activity, each student needed

- an aluminum pie pan,
- whole milk (enough to cover the bottom of the pan),
- food coloring,
- a toothpick,
- liquid dishwashing detergent (several different brands),
- and different types of milk (skim, 1 percent, or 2 percent) for substitutions.

Working individually, students cov-

Figure 2. Cat's Meow.

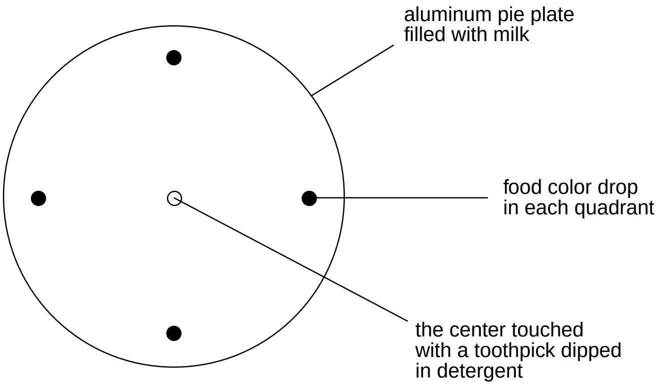


Table 1. Student Results.

Number of drops	**Type of milk**	**Type of detergent**	**Results**
1	skim	Price Chopper Blue	Good—green pushed others away
1	whole	Dove	Good—worked more than once
6	whole	Price Chopper Blue	Good—more color
12	whole	Price Chopper Blue and Dove	Good—awesome
1	whole	Dove	Spread a little
1	skim	Price Chopper Blue	Spread just like whole

ered the bottom of the pie pan with whole milk. Students put a drop of food coloring in each quadrant of the pan (see Figure 2).

The students then dipped a toothpick in detergent, touched it to the middle of the pan of milk, and made observations. Each student first performed the Cat's Meow activity using the same materials and made written observations.

This activity is particularly fascinating because the food colors swirl in different patterns across the surface of the milk due to the change in surface tension after adding the detergent.

Students were then asked to list the variables for the experiment across the top of a blank chart. Some variables they identified included the number of drops of food coloring, type of milk, and type of detergent. They were then asked to write an operational question involving one of the variables and test it themselves, using their initial results as a baseline.

Sample questions included, "What effect would three drops of each food coloring have? What effect would using skim milk have? What effect would changing the type of detergent have?" I was under the impression that the activity must be done with whole milk. The students discovered that skim milk works just as well. Volunteers were asked to share their results with the class, and the results were recorded on a transparency of the blank chart (see Table 1).

Assessment Methods

Assessment was not done in any formal means since this was a Saturday morning enrichment activity. Throughout each activity I attempted to determine how each group was doing. This was aided by having each group display their results at the conclusion of the activity.

One way to formally assess the activity would be to give students the description of an experiment they have not seen and have them:

1. Identify what can be changed (variables).
2. Propose a substitution, elimination, or increasing/decreasing question about one of the variables, and list the variables that must be held constant.
3. Design a plan to investigate the question.
4. Describe how they would communicate their results—what would their data table look like?

Such an assessment would be in agreement with the inquiry goals of the *Standards.*

Inquiry Insights

By having students modify traditional activities, it is possible to introduce them to the principles of experimental design. The modification of familiar activities provides a way to structure activities to teach the skills of observation, controlling variables, and asking operational questions.

As students become more familiar with these skills, the structure could gradually be removed, and more open-ended problem solving could take place. With groups of students answering their own operational questions, the teacher's role becomes more that of a facilitator of scientific research.

Resources

Allison, A., and Shrigley, R. (1986). Teaching children to ask operational questions in science. *Science Education, 70*(1), 73–80.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

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